THE RELATION BETWEEN FERROELASTICITY AND SUPERCONDUCTIVITY

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ABSTRACT

The high-temperature superconductivity is explained widely by the layered crystallic structure. The one- and two-dimensional subsystems and their interaction are investigated in this work. It is assumed that the high-Tc superconductivity takes place in the two-dimensional subsystem [1] and the increase of the phase transition temperature from 60 K up to 90 K is the consequence of turning on the influence of one-dimensional chains. The interaction between the two subsystems is transferred along the c axe by the phonons of breathing mode, what causes the hybridization of the electronic bonds between these subsystems [2].

The experimental works indicate that the existence of both the chains Cu(1)-O [3] and their interaction with the superconducting plane of Cu(2)-O modify the temperature of the transition to the superconducting state. It is seen from the neutron scattering data that the rates of the interatomic distance dependencies on temperature are changed around 240 K and 90 K [4]. The "zig-zag" order in Cu(1)-O chains has been postulated [4], but, on the other hand, the vibrations with a large amplitude only were reported [5].

The bi-stabilized situation of the oxygen ions can be caused by the change of distance between these ions and the Ba ions [4]. It leads to the appearance of a two-well potential [6]. Its parameters depend on temperature and the determine the dynamics of the oxygen ions' movement. They can induce the antipolar order, which can be, however, more or less chaotic.

The investigation of the ferroelastic properties of Y-Ba-Cu-O samples lead to the conclusion that they are related to jumps of ions inside the given chain and not to a diffusion between different sites in the ab plane [7]. We deduce thus that the fluctuating oxygen ions from these chains create dipols in the ab plane. They can be described with the pseudo-spin formalism / - Pauli matrices/. The system can be described with Ising model:

$$H_s = -\frac{1}{2} J \sum_{i,j} \sigma_{3i} \sigma_{3j} \tag{1}$$

The pseudo-spins interact with phonons and influence the superconductivity in the second subsystem:

$$H_{sI} = \sum_q \sum_i \gamma_i(q) \sigma_3 (b_{q,i} + b_{-q,i}) \tag{2}$$

The Ising model in the molecular field approximation / though fully correct in the one-dimensional case/ gives the phase transition for the anti-polar order parameter:

$$< \sigma_{3i} > = (-1)^i \eta \neq 0 \tag{3}$$

The effective field conjugated to the pseudo-spin interacts with the ferroelastic order like an external magnetic field with a real spin system:

$$H' = B_z \sigma_3 \tag{4}$$

$$B_z = 2 \xi_0 \gamma(o) = A' u \tag{5}$$

where u denotes condensation of phonons of breathing mode /deformation of pyramids/:

$$u = (h/2M)^{1/2} (\xi_0 + \xi_0^+) \tag{6}$$

We obtain the description of the relation between the superconductivity and ferroelasticity in such a way.

References

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